SOLUTIONS TO GAVINS POINT TAINTER GATE ICING PROBLEMS

Ronald W. Bockerman
CENWO-OD-TM
402-221-4197

Philip A. Wagner
CENWD-MR-ET-E
402-697-2651

ABSTRACT

The Gavins Point Project on the Missouri River near Yankton, SD, includes an earth dam with two alternative methods for making releases, a hydroelectric power plant and a concrete spillway structure. The Gavins Point Project provides regulated releases into approximately 1305 Km (811 miles) of the Missouri River between Yankton, South Dakota and St. Louis, Missouri.

By the early 1970's, it was realized that at least three tainter gates must always be available during the winter months to make discharges if partial or complete powerhouse discharge capability is lost. There are no flood control tunnels or bypass valves.

The spillway at the Gavins Point Project has fourteen, 12.19 meters (40 feet) wide by 9.14 meters (30 feet) high, tainter gates. The spillway was designed for a discharge capacity of 16,537 cms (584,000 cfs). The original design included side seal heaters and an air bubbler system to keep the tainter gates free of ice. Tainter gate freezing problems have been encountered since the original closure of the dam in 1955. The capability to reliably make extended discharges during extremely cold weather is required to assure an adequate water supply and to minimize downstream ice problems.

Over the years, the Gavins Point Project has tried several modifications and operating procedures to keep the gates operable during the winter months. These include modifications to the side seal heaters, adding wall heaters, adding a bubbler system to the lower portion of the gates, cycling the gates, and removing ice with hand held fire hoses.

This paper discusses past, present, and feasible future alternatives to assure reliable operation of the tainter gates at the Gavins Point Project.

INTRODUCTION TO GAVINS POINT PROJECT

As part of the 1944 Pick-Sloan Plan, construction of the Gavins Point Dam (Lewis & Clark Lake) began in 1952 and was completed in 1957 at a cost of $51 million. Gavins Point, smallest of the six dams that comprise the upper Missouri River Basin main-stem system, plays a key role in the successful operation of the Pick-Sloan Plan for development of the Missouri River Basin. Peaking releases from the upstream Fort Randall powerhouse are smoothed by constant Gavins Point releases, providing uniform flows on the open river between Yankton, South Dakota and St. Louis, Missouri. The Gavins Point Project benefits include power generation, flood control, water supply, recreation, navigation support, and fish and wildlife enhancement. The project is part of the Omaha District, Missouri River Region, Northwestern Division of the US Army Corps of Engineers. It is located on the Nebraska/South Dakota border and the Project Manager is Mr. Michael R. Knoff.

PREVIOUS SOLUTIONS TO MINIMIZE ICING PROBLEMS ON TAINTER GATES

DESCRIPTION OF THE PROBLEM:

Past experience indicated that ice forming in the downstream corners of the tainter gate between the gate and the adjacent pier wall is the major reason the gates are often not operable during the winter months. A column of ice builds up in the corner, literally freezing the structural members on the downstream side of the gates to the concrete pier walls **(see Photo A).** If the ice columns become large enough, the gate hoists cannot break the ice bond and lift the gates.

The ice column is the result of two conditions. One, failure of the side seals to effectively seal near the top of the gate allows water to leak past all winter, forming and gradually increasing the size of these columns. The J-Type seals rely on differential pressure (head) to seal. Near the surface of the lake there is not sufficient water pressure to cause a tight seal, compounded by the fact that cold, winters temperature causes the seals to become hard and less flexible.

Two, the pool level behind Gavins Point Dam is maintained within three feet of the top of the tainter gates during the fall and winter months when there is little risk of large inflows. Most years when the ambient temperature drops significantly and consistently below freezing, the lake remains relatively calm until it freezes over. Occasionally before the lake freezes over, low temperatures are accompanied by high winds causing waves to splash over the top of the gates, forming ice on the downstream structural members. Once the lake freezes over, water splashing over the top of the gates does not occur but, by then there may already be considerable ice build up. This ice build up is slow to melt because the orientation of the spillway is such that little sunlight gets to it during the winter months.

Other less significant factors add to the problem. The air bubbler nozzles embedded upstream of each gate to prevent ice from forming immediately upstream of the top of the gates do not keep the bottom of the gate from freezing. The constant emission of air supplied by compressors through rows of nozzles imbedded in the concrete invert cause the relatively warm water at the bottom to circulate to the surface preventing ice from forming at the water surface. However, the nozzles are not close enough to the bottom of the curved gates to prevent ice from forming at the bottom sill. Also, limited leakage past the bottom seal and occasional splashing over the top of the gates, can create ice that bonds the bottom of the gates to the downstream concrete ogee section. The wall heaters described herein do little to alleviate ice formed by these two factors.

PREVIOUS ATTEMPTS TO PREVENT OR REMOVE ICE:

The spillway structure was originally equipped with the bubbler system noted above to keep ice from forming at the water surface immediately upstream of the gates and with side seal heaters to keep the seals free of ice. These systems are still in place and are working as intended. The side seal heaters for the subject three gates were replaced in kind because of their condition and age.

Over the past 30 years, the project has tried various things to solve the icing problems including the following:

1. Three gates were equipped with higher capacity side seal heaters in hopes that, not only would they keep the imbedded seal plates and seals warm, some additional heat would warm the pier walls where the ice columns form. These added little, if any, benefit and eventually experienced electrical failure.

2. New J-seals of a softer compound were purchased to replace the original seals that had become worn and hard. This reduced the leakage but did not provide a watertight seal.

3. Wedges were manually driven behind the upper portion of the J-seals, forcing the bulb into the seal plate, resulting in a better seal. Unfortunately, the wedges were only temporary and were dangerous to install.

4. To prevent waves from splashing over the gates before the lake freezes over, an experimental wooden stop log was mounted near the surface of the lake in one gate slot. The object was to break up the waves before they reached the gate. This experiment was inconclusive because a storm destroyed the stop log before reaching the critical period just before the lake froze over. This effort may be repeated in the future.

5. Additional bubblers were added near the bottom of one gate to reduce ice build up in that area. It is not known how effective that measure was but it is certain that adding bubblers is not the total solution. The hardware itself eventually failed from freezing and was removed.

6. Anticipating that some gates would have to be operated during the winter of 1996-97, the Gavins Point staff tried cycling a couple of the gates open and closed. This resulted in very limited success and, in fact, resulted in one gate being frozen slightly open for a time. Discharging also rendered the bubbler system ineffective, resulting in ice formation upstream of the gates.

7. When it was necessary to open a couple of gates during the winter of 1996-97, the staff attempted to remove the ice columns with fire hoses spraying heated water. Some progress was made but the work was tedious and dangerous. Fortunately, the effort was helped by a break in the weather. In sub-zero temperatures, this method would not have been effective.

8. Several years ago, Gate No. 5 was provided with wall heaters of a different construction than is described in this article but of approximately the same capacity and covering about the same area. This hardware eventually failed but not before giving us a good indication that properly sized and located wall heaters helped solve the tainter gate icing problem associated with cold weather operation. This experiment lead to the design, purchase, and installation of the wall heaters described in this article on Gates No. 2, 6, and 8.

Other weather related problems can still be experienced during actual discharge such as drifting and freezing of water mist, and ice bridging on the face of the gate from loss of effectiveness of the bubbler system. These problems will be further analyzed during future winter operations.

DESIGN OF PRESENT WALL HEATERS FOR TAINTER GATES

WALL HEATER DESIGN CRITERIA:

The idea for the present wall heaters came from REMR Technical Report HY-14 (Attachment B) which presented research on side wall heaters for a miter gate recess. The concept consisted of two rectangular aluminum plates separated by an aluminum spacer with self-regulating heat cable serpentined between the two plates. One test panel was built and successfully tested at Starved Rock Lock and Dam.

Discussion with Robert Haehnel of Cold Regions Research and Engineering Laboratory (CRREL) resulted in a tainter gate side wall heater, conceptual design using the same ideas used at Starved Rock Lock and Dam. The present design uses custom shaped aluminum panels and higher wattage heating elements. Calculations performed by CRREL suggested a design heating density for the panels of 6.04 watts/sq. meter (65 watts/sq. ft).

WALL HEATER ALUMINUM PANELS:

Sectional aluminum panels consisting of 4.76 mm (3/16 inch) inner and outer panels separated by 12.7 mm (1/2 inch) aluminum rectangular spacers were made by a sheet metal fabricator **(see Photo B)**. The panels were made in three sections and assembled and inspected in his shop before shipment to the Gavins Point Project. The panels were laid out on the generator floor for a final check-fit of the heating element. The heating elements were procured independent from the aluminum panels and required forming to fit the panels. Each section weighs approximately 68.04 kg (150 pounds).

Since the aluminum panels are fabricated from standard aluminum sheets, they can be competitively procured from numerous sheet metal fabrication contractors. They can be customized for any required configuration and they are not a proprietary product of any manufacturer. The design requirement would be a specification for the materials and drawings showing what the contractor is required to fabricate. In this case, the panels were designed to follow the curvature of the gate with a tapered leading edge to help provide a smooth flow of water past the panels when the gates are open. The panels were secured to the pier walls by drilling and inserting concrete anchors and 9.52 mm (3/8 inch) stainless steel bolts. With the covers removed, the panels were used as templates to locate the anchors. The panels are designed to permit installation and removal of the elements through the top without removing the covers. For the initial installation, the elements were placed in the panels before the removable covers were installed.

WALL HEATER HEATING ELEMENTS:

The heating element heating density requirement was greater than what could be supplied by the self-regulating heat cable used in the test panel at Starved Rock Lock and Dam. Mineral insulated (MI) cable was selected as an alternative heating element that could provide the higher heating density **(see Photo C)**. MI cable is similar to the heating element used in residential ovens. This product can be ordered in various wattages/linear foot, lengths, sheathing styles, terminations, and is available from numerous manufacturers and can be competitively procured.

SIDE WALL HEATER TEMPERATURE CONTROL:

Solid state relays (SSR) instead of mechanical contactors were selected to control the temperature of the sidewall heaters. An SSR is a normally open switching device with no moving parts. Applying a control signal to the SSR switches it "ON" and provides the AC load current to the heaters. The switching takes place at a zero voltage crossover point in the AC sinewave. The solid state relay can provide both on/off and proportional control of the heating loads by varying the frequency and duration of the SSR switching. This precise control would normally not be required for side wall heater applications, it just happens to be a side benefit that results in energy savings. The important features of the SSR for this application are that they are inexpensive, rugged, and maintenance free. SSRs are available in various sizes and the ones used for this work cost approximately $50 per panel. One SSR can control the four heating elements in a panel in a parallel arrangement. A 50-amp breaker was placed ahead of the SSR to provide protection from short circuits and overloads.

The control signal for the SSR is provided by an auto-tuning, single-loop temperature controller with proportional, integral, and derivative (PID) control. The controller can adjust the duration and frequency of the on/off pulses to the SSR. This capability allows the controller to precisely match the side wall heater temperature to the controller set point which is adjustable. A three-wire resistance temperature device (RTD) embedded in the side wall heater provides the temperature input to the controller. The controller can display either the set point temperature or the actual side wall heater temperature. The controllers used for this work cost approximately $200 per panel.

The SSR and temperature controller were placed in a NEMA 4X enclosure. A cabinet heater was provided to maintain the enclosure environment within the limits required by the temperature controller (noncondensing, 0-65.56 degrees C)(noncondensing, 32-150 degrees F). The temperature controller has a NEMA 4X face and is mounted through the face of the enclosure for viewing. The enclosure was the most expensive electrical component. Also, in the enclosure is a 20-amp breaker for the side seal heaters. The 4 kW side seal heater operates continuously during the winter and does not have temperature control equipment. All of the heaters are turned off during the summer.

CONTRACT MANAGEMENT AND CONSTRUCTION OF PRESENT WALL HEATERS

The contract (DACW45-97-P-0505) to fabricate the aluminum wall heater panels was awarded to Hemple Sheet Metal Works Inc. 1255 South 13th St., Omaha, NE 68108, telephone (402) 341-4305, for a total of $51,200. The company's point of contact was Mr. Dave Hemple. The contract requirements were completed in approximately 90 days.

The contract (DACW45-97-P-0583) to furnish the heating elements and controls was awarded to Hotfoil Incorporated, 7 B Marlen Drive, Robbinsville, NJ 08691, telephone (609) 588-0900, for a total of $33,924.

The wall heaters were assembled, installed, and tested by the Gavins Point maintenance staff over a period of approximately 30 days.

FUTURE SOLUTIONS TO MINIMIZE ICING PROBLEMS ON TAINTER GATES

HOLLOW J-SEAL HEATERS:

The current J-seals are solid rubber and depend upon heat from the existing side seal heaters to keep the rubber pliable for a good seal. Since the cold water and ice are in contact with J-seal, it ends up being the same temperature as the water and ice and becomes less pliable. An enhancement for the side seals would be to install hollow J-seals that would allow self-regulating heat cable to slide into the vertical J-seal and keep it warmer and more pliable which would provide a better seal with the side seal heaters.

STRUCTURAL MEMBER HEATERS:

The existing trunnion arms on the tainter gates do not have any heaters attached which would limit ice forming on the gates from leakage past the J-seals or water splashing over the top during fall freeze-up. The concern would normally be bridging of ice between the trunnion arm and the adjacent concrete wall which would limit movement of the trunnion arm. These heaters would supplement the current wall heaters if they are not able to disbond the ice so the gate can open.

SKIN PLATE BUBBLERS W/HEATERS:

The existing tainter gate bubbler system at Gavins Point is located in the ogee section of the spillway several feet from the face of the tainter gate. The air does a good job of keeping the ice off the top surface of the gate. In the closed position the bottom of the gate slopes away from the ogee section and no movement of water occurs near the bottom gate seal and the spillway. It is not currently known how much ice builds up in this area and attempts to determine the quantity is ongoing. A past attempt to provide air to this area of the gate failed because water would get into the air lines on the back side of the gate and freeze and stop the air flow to the bottom of the gate. Information presented in REMR Technical Report HY-14 suggests that air bubblers incorporating electric heaters are more successful than bubblers alone. Heating elements and air bubblers with piping wrapped with self-regulating heat cable could be installed on the back side of the gate, close to the bottom seal. The air would then sweep the face of the tainter gate and cause warmer water to circulate into the area and keep the seal area free of ice.

DEFLECTOR PLATES:

Another idea being considered involves the addition of some steel plates to the top of the gates designed to deflect waves toward the center of the gates away from the corners where the problem ice columns form. These would only be potentially effective for the high wind/wave action just before the lake freezes over condition previously described. Whether or not we experiment with this idea will depend on the effectiveness of the wall heaters.

SUMMARY

The primary idea to be retained from this paper is the concept of building nonproprietary heating panels from off-the-shelf, readily-available materials. The heating panels can be made from stock aluminum sheeting fabricated in any configuration required. The heating element that goes in the panel can be self-regulating heating cable or MI cable which is readily available from many sources. The controls can be as simple as a manual on/off switch, opening and closing a manual contactor, or as sophisticated as a remote temperature sensing element mounted on the heating panel with a controller automatically switching a SSR. The installation can be accomplished by project or contractor personnel and the various components (aluminum panels, heating elements, breakers, panels, and controls) could be government furnished or contractor furnished.

Although gate operations and discharges were made during the first winter following the wall heater installations, 1997/1998, it was a mild winter and conditions did not provide a complete, comprehensive test of this new equipment. It may take several winters before all of the potential icing conditions are experienced and we know that we have solved our winter gate operating problems. However, the first winter did show that the wall heaters are physically reliable and are effective in preventing ice formation in the critical area where they are located.

Should you decide to incorporate the ideas and designs described in this report into some future work, you may want to contact one of the authors to get updates on the success of the operation of the wall heaters.

ACKNOWLEDGMENTS

Robert B. Haehnel
Research Mechanical Engineer
Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, NH 03755
603-646-4325

Bob Haehnel was responsible for providing the technical research for the design of the side wall heaters.

Kennard E. Martin
Mechanical Engineering Technician
CENWO-ED-DA
215 North 17th Street
Omaha, NE 68102
402 221-4463

Ken Martin was responsible for providing the specifications and drawings for the fabrication of the aluminum panels.

Gary A. Hinkle
Electrical Engineer
CENWO-OD-TM
215 North 17th Street
Omaha, NE 68102
402-221-4684

Gary Hinkle was responsible for providing the specifications and drawings for the purchase of the heating elements and controls.

Gavins Point Project Staff
CENWO-OD-GP
Yankton, SD
402-667-7873

Mike Erickson, Charlie Gauker, Willie Gramkow, Dale Stibral, Gary Gross, Gary Copperstone, Curt Bisgard, Dennie Stark, and Jon Gartner, were responsible for the installation of the wall heaters and the new side seal heaters.

REFERENCES

1. EM 1110-2-1612 - Ice Engineering, 15 October 1982

2. REMR Technical Report HY-14, September 1997

AUTHORS' ADDRESSES

Ronald W. Bockerman
CENWO-OD-TM
215 North 17th Street
Omaha, NE 68102
(402) 221-4197

Philip A. Wagner
CENWD-MR-ET-E
12565 West Center Road
Omaha, NE 68144
(402) 697-2651

ATTACHMENTS

Attachment A - EM110-2-1812 (Front page only)
Attachment B - REMR Technical Report HY-14 (Front page only)
Attachment C - Photographs - Photo A, B, and C
Attachment D - Drawing - Gate Section
Attachment E - Drawing - Wall Heater w/o Cover
Attachment F - Drawing - Cover Plates
Attachment G - Drawing - Cover Plates
Attachment H - Drawing - Control Panel & Schematic

ENGINEER MANUAL

EM 1 1 1 0-2-1 812
15 OCT 1982

ENGINEERING AND DESIGN

ICE ENGINEERING

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
OFFICE OF THE CHIEF OF ENGINEERS

Attachment A

Repair, Evaluation, Maintenance, and Rehabilitation Research Program

Technical Report REMR-HY-14
September 1997

Ice Control Techniques for Corps Projects

by F. Donald Haynes, Robert Haehnel,
Charles Clark, Leonard Zabilansky

U.S. Army Cold Regions Research and Engineering Laboratory
72 Lyme Road
Hanover, NH 03755 1290

Final report

Approved for public release; distribution is unlimited

Prepared for
U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32659

Monitored by
U. S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, MS39180-6199

Attachment B

PHOTO A
ICE COLUMN FREEZES
GATE TO PIER WALL

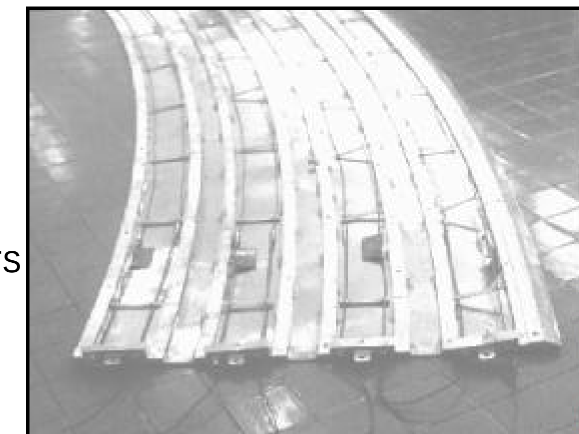

PHOTO B
AL BACK PANEL W/O COVER
PANEL W/MI CABLE IN SLOTS

PHOTO C
MI CABLE W/SPACERS
READY TO INSTALL IN
BACK PANEL

Attachment C